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(54) Title: PRESERVATION OF EXPOSED UNDERGROUND PLANT STRUCTURES

(57) Abstract

The present invention relates to a method for preserving exposed underground plant structures which comprise applying an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent to the exposed plant structure. The present invention also relates to a composition for preserving exposed underground plant structures which comprises an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent.

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PRESERVATION OF EXPOSED UNDERGROUND PLANT STRUCTURES

The present invention generally relates to a method and a composition for preserving exposed underground plant structures and is particularly directed to a method and a composition for preserving peeled, damaged or cut underground plant structures, such as potatoes, so that they are microbiologically safe for human consumption and can be stored for long periods of time without appreciable loss of natural flavour, colour and texture.

Sulfite containing compounds have previously been used to inhibit browning in potatoes which are peeled, damaged, cut or otherwise have their tissue exposed to air. Sulfite containing compounds also have an antimicrobial action. Unfortunately, the use of sulfite in conjunction with fresh produce causes softening and off-flavour. Sulfite containing compounds are commonly used in conjunction with gas impermeable vacuum packaging and refrigeration to reduce undesirable changes in texture and off-flavour. Vacuum packaging generally creates anaerobic conditions which are conducive to anaerobic fermentation and could produce off-flavours and promote the growth of pathogenic organisms. Sulfite has also been linked to illnesses, mainly among asthmatics. Adverse health effects associated with sulfite usage, increased regulatory scrutiny and increased consumer preference for fresh natural foods have stimulated the search for a practical and functional alternative to sulfite containing compounds.

Browning of peeled potatoes is unaesthetic and perceived by consumers and processors to indicate spoilage. One of the chemical reactions which causes browning of potato tissue is commonly referred to as enzymatic browning. In unpeeled, undamaged or uncut potatoes, natural phenolic substrates are separated from the enzyme responsible for browning and browning does not occur. Once the potato tissue is peeled, damaged, cut and exposed to air, rapid browning occurs due to the enzymatic oxidation of phenols to orthoquinones. The orthoquinones rapidly polymerise to form brown pigments or melanins. The enzymes which catalyse this oxidation are commonly known as phenolase or polyphenol oxidase, tyrosinase and catecholase.

For enzymatic browning to occur, four essential components must be present: oxygen, enzyme, copper and substrate. To maintain some control over enzymatic browning, one or more of the essential components needs to be eliminated from the reaction. Removing oxygen from the exposed surfaces of potatoes is difficult and impractical. Potatoes and other produce also require oxygen to maintain normal respiratory activity. Furthermore, lack of oxygen could favour the growth of anaerobic pathogenic organisms.

Phenolase enzymes are naturally occurring in potatoes and are not easily removed therefrom. For example, heat treatment or blanching to remove phenolase enzymes causes undesirable softening and formation of black discolouration ("after-cooking darkening"). The use of chelating agents to bind copper only slows the browning reaction and does not completely eliminate its occurrence. EDTA (ethylenediaminetetaacetic) or its sodium salt, phosphate based compounds such as sodium acid pyrophosphate and citric acid have been investigated as suitable chelating agents, but have been shown to be unsuccessful in preventing phenolase browning.

A number of anti-browning agents and/or treatments including anti-oxidants or reducing agents, acidulants, chelating agents, phenolase inhibitors, inorganic salts and enzymes have been investigated, but are not in commercial use. At present, the best alternative to sulfite containing compounds is the use of citric acid with ascorbic acid as anti-browning agents. Using dipping procedures, a shelf-life of 4 to 7 days can be achieved. A serious shortcoming in the use of anti-browning agents is their limited penetration into the vegetable compared to that of sulfite. Vacuum and pressure infiltration techniques, employing a relatively high vacuum, have been used as a freezing pre-treatment to prevent browning in apple and potato slices by replacing tissue gases with aqueous solutions of anti-browning agents including ascorbic acid. However, vacuum infiltration has been reported to produce a water-logged or translucent appearance that would not be acceptable in a fresh product.

The potato is ne f the world's most valuable food crops. The current production level of potatoes alone is estimated to be worth $US90 billion. By volume,

potato ranks fourth in the world after rice, wheat and maize with about 300 million tonnes annually produced. Potatoes have been commercially produced in Europe and the USA for over 200 years, but it is relatively new crop for many of the developing countries, although now, potato productivity is increasing in developing countries at a rate nearly twice that of most other food crops.

A method and a composition which inhibit phenolase browning of peeled, damaged or cut potatoes and replace the existing use of sulfite containing compounds without an appreciable loss of natural flavour, colour, texture and which are microbiologically safe would be important advancements in the potato industry as well as the vegetable and food processing industry in general.

According to one aspect of the present invention there is provided a method for preserving exposed underground plant structures which comprises applying an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent to the exposed plant structure.

According to another aspect of the present invention there is provided a composition for preserving exposed underground plant structures which comprises an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent.

The present invention also provides a kit for preserving exposed underground plant structures which comprises:

(a) an edible coating which acts as a carrier for an anti-browning agent; and

(b) at least one anti-browning agent,

said components (a) and (b) being held in the kit separately for simultaneous, sequential or separate use.

The term "exposed underground plant structure" is used herein in its broadest sense and includes the tissue normally covered by the skin of the underground plant and which is exposed when the plant is peeled, damaged, cut or otherwise exposed. The

plant tissue may be raw or cooked. Suitable examples of underground plants include stem tubers, such as, for example, potato and sweet potato; swollen taproots, such as, for example, carrot; and swollen hypocotyl, such as, for example, beetroot; and bulbs or underground buds, such as, for example, onion. Preferably the tuber is potato.

The edible coating may be of any suitable known type provided it is capable of acting as a carrier to effectively expose the peeled, damaged or cut plant structure to the anti-browning agent. Preferably the edible coating has good film-forming properties under moist and refrigerated conditions. Suitable edible coatings include polysaccharide gums, such as, alginate or derivatives thereof, for example, sodium, potassium, ammonium, ammonium-calcium and sodium-calcium salts of alginic acid and propylene glycol alginate; vegetable gum; agar; modified starch; microbial polysaccharides, such as, for example, gellan gum; or mixtures thereof.

The formation of the edible coating may be assisted by the use of food additives known in the art. Such food additives may include emulsifying, gelling, stabilizing, thickening and firming agents. A particularly suitable food additive is a source of calcium ions as this is capable of reacting with alginates and other polysaccharides or derivatives thereof to form edible gels. The source of calcium ions may include calcium carbonate, sulphate, chloride, phosphate, lactate or tartrate. The rate of gel formation as well as the quality and texture of the resultant gel can be controlled by the solubility and availability of the calcium source. Calcium chloride is preferred as it is readily soluble in water and causes the instantaneous formation and precipitation of calcium alginate. As will be apparent hereinafter, calcium chloride is also effective as an anti-browning agent.

The anti-browning agents may be of any suitable known type and include anti-oxidants or reducing agents, such as, sulfhydryl compounds, for example, L-cysteine; ascorbic acid or derivatives or isomers thereof, for example, erythorbic acid; acidulants, such as, citric acid or derivatives or isomers thereof; chelating agents, such as, ethylenediaminetetraacetic acid (EDTA) or sodium acid pyrophosphate; phenolase inhibitors; inorganic salts, such as, calcium salts, for example, calcium carbonate,

sulphate, chloride, phosphate or tartrate; enzymes; and mixtures thereof.

A preferred combination of anti-browning agents suitable for use in the method of the invention is an antioxidant or reducing agent, such as, ascorbic acid or derivatives or isomers thereof; an acidulant to lower the pH, such as, citric acid or derivatives or isomers thereof; and calcium chloride.

Ascorbic acid and its isomer, erythorbic acid, have frequently been used interchangeably as anti-oxidants in the food industry. Their function in food systems is to act as free radical scavengers and thereby prevent oxidation, alter the redox potential of the system and reduce undesirable oxidative products. The main role of ascorbic and erythorbic acid in the prevention of enzymatic browning is their ability to reduce the orthoquinones to colourless diphenols.

Citric acid which functions as an acidulant is believed to have a dual inhibitory effect on phenolase by reducing pH and chelating copper at the enzyme-active site. The optimum pH of phenolase activity varies with the source of the enzyme and the particular substrate, but generally it has an optimum pH in the range of 6 to 7. Fresh potatoes have a pH of 5.4 to 5.8. Phenolase preparations from several sources are reported to be inactivated below pH 4.0. Hence, the role of an acidulant is to maintain the pH well below that necessary for optimal catalytic activity.

In addition to acting as a gelling agent, calcium chloride may also act as an anti-browning agent. The inhibition of chloride is pH dependent and increases as the pH is reduced, with the maximum inhibition being in the pH range of 3.5 to 5.0. The pH effect on the inhibition by chloride may be explained by the interaction between the negatively charged inhibitor and a positively charged imidazole group at the active site of phenolase. The use of calcium chloride has the added advantage of maintaining the firmness of the tissue by interacting with pectin in the cell walls of the plant structure and acting as a gelling or firming agent for the edible coating, in particular sodium alginate.

In a preferred embodiment, the edible coating is sodium alginate and/or agar and the anti-browning agents are ascorbic or erythorbic acid, citric acid and calcium chloride which also functions as a gelling or firming agent for the sodium alginate.

It will be appreciated that the choice of edible coating will depend on the ultimate consumer. Some may prefer a coating which has a low viscosity and is less visible, while others may prefer a high viscosity coating which is thicker so that it can be easily peeled.

The concentrations of edible coating and anti-browning agent used are preferably kept to a minimum. In one embodiment, about 0.5 to about 3% (w/v) sodium alginate and/or about 1.0 to about 3% (w/v) agar are used as the edible coating and about 1 to about 4% (w/v) ascorbic or erythorbic acid, about 0.25 to about 1% (w/v) citric acid and about 1 to about 2% (w/v) calcium chloride are used as browning agents.

The edible coating and anti-browning agent may be applied to the exposed plant structure simultaneously, sequentially or separately by any suitable technique, such as, for example, by immersing the exposed plant tissue in solutions of the edible coating and anti-browning agent or by curtain coating or spraying solutions of the edible coating and anti-browning agent onto the exposed plant structure. When sequentially or separately applied, the edible coating and anti-browning agent may be applied in any order. The edible coating is generally applied before the anti-browning agent so that the anti-browning agent can adhere to the coating.

It will be appreciated that other conventional food additives such as flavourings, flavour enhancers, colorants and vitamins may be incorporated into the edible coating.

The underground plant having an exposed structure which is preserved by the method of the present invention is also novel *per se*.

Thus, the present invention also provides an underground plant having an exposed structure which is coated with an edible coating which acts as a carrier for an

anti-browning agent and at least one anti-browning agent so as to preserve the exposed tissue.

The preserved plant of the invention is advantageously stored in a package so as to maintain the aerobic conditions required for regular respiratory activity of the plant. Anaerobic conditions or the absence of oxygen could result in off-flavour development particularly in peeled potatoes and could facilitate growth and toxin production by microorganisms, such as, for example, *Clostridium botulinum* at storage temperatures above 4 to 5°C. We have found that the storage life of the exposed plant structure can be extended up to 28 days if a semi-permeable package is used.

According to a further aspect of the present invention there is provided a method for preserving exposed underground plant structure which comprises the steps of:

(a) applying an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent to the exposed plant structure; and

(b) storing the coated exposed plant structure in a semi-permeable package.

The term "package" is used herein in its broadest sense and includes any means for containing the exposed plant structure, such as, for example, a parcel, film, container, box or bag. The package may be unsealed or sealed, such as, for example, by vacuum or heat sealing.

Preferably the package is semi-permeable to oxygen and carbon dioxide so an equilibrium concentration of both gases is established when the rate of gas transmission through the package is equal to the rate of respiration (hereinafter referred to as an "equilibrium - modified atmosphere"). The equilibrium-modified atmosphere in the semi-permeable package will depend on various parameters including rate of tuber respiration, fill weight, the gas permeability of the package and the surface area for gas exchange. Preferably, the equilibrium-modified atmosphere in the package is about 1 to about 10% oxygen and about 1 to about 10% carbon dioxide under refrigerated conditions.

The semi-permeable material from which the package is wholly or partly composed may be selected from a single or multilayer polymeric film having an oxygen transmission rate (OTR) of about 2,400 to about 4,000 cc/m^2-day (2°C, 92% relative humidity). The OTR value at standard conditions (23°C and 70% relative humidity) is about 4,000 to about 8,000 cc/m_2-day. Preferably, the semi-permeable material is a single layer polymeric film of 50-55 micron low density polyethylene.

The present invention further provides a package for preserving exposed underground plant structures which comprises a semi-permeable material containing an underground plant having an exposed structure which is coated with an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent.

Preferably, the preserved plant and/or package containing the preserved plant are stored at temperatures below about 10°C, preferably in the range of about -1°C to about 5°C.

The present invention has the advantage of substantially preventing discolouration thereby improving the aesthetic appearance and taste of exposed underground plant structures. This discolouration may be browning in the case of peeled and/or cut potatoes or whitening probably due to lignin formulation in the case of peeled and/or cut carrots and onions.

The invention will now be described with reference to the following Examples. These Examples are not to be construed as limiting the invention in any way.

In the Examples, reference will be made to the accompanying drawings in which:

Fig. 1 is a graphical representation showing the visual score during storage of treatments T1 to T8 of Example 1 (Score 10 - Fresh Like : 5 Marginal);

Fig. 2 is a graphical representation showing the change in hue angle during storage of treatments T1 to T8 of Example 1 (90 Degree : Yellow);

Fig. 3 is a graphical representation showing the development of surface discolouration as whiteness index of the carrot baton surfaces of Example 7

; and

Fig. 4 is a graphical representation showing the surface discolouration as whiteness index of the cut onion surfaces of Example 8

EXAMPLE 1

The object of this experiment was to determine the range of concentrations of selected anti-browning agents that could inhibit enzymatic browning in peeled whole potatoes.

Approximately 130g of sound and firm Sebago potatoes (*Solanum tuberosum*) were hand-peeled and then temporarily stored under water for 10-30 minutes. The coating and anti-browning agents were applied in two stages: (1) Solution I was an alginate solution (3.0% w/v of Manugel GHB (Registered Trade Mark), Kelco); and (2) Solution II was a combination of various anti-browning agents and calcium chloride (2 % w/v). Table 1.1 below shows the various concentrations of anti-browning agents in Solution II. There were 7 solutions (T1 to T7) investigated. All solutions were prepared at room temperature and stored at 4 ± 0.5°C overnight. Each peeled potato tuber receiving the coating was immersed into Solution I for about 1-5 minutes, and allowed to drip, followed by immersion into Solution II which resulted in a clear homogenous coat/film over the entire surface of the potatoes. After draining in a colander, 4 peeled tubers were placed in a semi-permeable plastic bag (175 x 190 mm). Preliminary work suggested that this packaging film would could produce a useful aerobic equilibrium-modified atmospheres of about 1-10% O_2. All plastic packages were heat sealed using a manual sealer (Venus Model VH400). An additional treatment (T8) which acted as the control was prepared by dipping the peeled potatoes in water. There were 3 replicates per treatment. Treated samples and controls were stored at 4 ± 0.5°C for as long as 22 days.

Table 1.1 - Whole Peeled Potat Treatments

Treatment	AA* (%w/v)	CA* (%w/v)	SAPP* (%w/v)
T1	4	1	1
T2	4	1	-
T3	2	0.5	0.5
T4	2	0.5	-
T5	1	0.25	0.25
T6	1	0.25	0.25
T7	"Coating only"		
T8	"Dipped in water"		

* Note: AA- Ascorbic Acid, CA - Citric Acid, SAPP - Sodium acid pyrophosphate

T1 to T7 - also contained 2% $CaCl_2$ as a gelling agent.

Treatment effectiveness was evaluated by measuring colour changes at the peeled surface of treated samples and controls during storage. To measure colour objectively, the CIELAB's "*L*" (light-dark), "a" (red-green) and "*b*" (yellow-blue) for a selected surface were measured using a Minolta Chroma meter, Model CR300 with a 8mm specimen port. For each treatment, a total of 18 measurements were taken (6 measurements per bag of sample). To evaluate the change in colour, hue angle was also calculated from the tristimulus data. Hue angle values of 0°, 90°, 180° and 270° indicate red, yellow, green, and blue, respectively. Hue angle values close to 90° indicate browning.

A subjective visual evaluation was also conducted to assess the change in colour during storage. A scoring system described in Table 1.2 below was used to subjectively assess the visual acceptability of fresh peeled potatoes. A colour score of "6" and below was considered unacceptable.

Table 1.2 - Visual Scoring System for Fresh Peeled Potat es

Score	Description
10	Extremely desirable, no defects
9	Very desirable, very slight drip
8	Desirable, slight drip
7	Slightly desirable, slight browning <50% of tubers
6	Slightly undesirable, slight browning >50 % of tubers
5	Undesirable, moderate browning >50% of tubers
4	Very undesirable, extreme browning and other defects

Oxygen and carbon dioxide levels in the packages were measured by injecting 20 ml of gas sample drawn from the package into a "MAPtest 4000" gas analyser (HiTech Instruments, U.K.). The gas analyser uses a zirconia oxygen sensor and an infra-red carbon dioxide sensor. The accuracy of measurements was about ± 1 % of the reading.

Compression tests (Lloyd, Model 1000R, U.K, 100 N load cell, crosshead speed 20mm/min, 8mm diameter flat plunger) were performed on a flat surface of 8 randomly selected potatoes (coat removed). The maximum load encountered during a 3 mm penetration on the surface was taken as a measure of the firmness or softness of the potatoes.

Results and Discussion

The results of visual and CIELAB colour assessments are shown in Figures 1.1 and 1.2. Based on visual score, it is possible to store peeled potatoes for up to 22 days with acceptable appearance. In contrast, control samples dipped in water were found to be acceptable only up to the 3rd day of storage with a visual score of 6 (limit of acceptability). Treatments T1, T2, T3 and T4 were found to give similar degree of browning inhibition. However, T4 would require the least amount of anti-browning agents amongst these four potential treatments to achieve similar levels of effectiveness.

Hue angle calculated from a and b values was found to have a high degree of correlation with visual score (r = 0.90). Samples used in this study exhibited an initial hue angle of about 100°. A reduction in hue angle indicates browning or yellowing. A hue angle of about 95 ° corresponds to a visual score of about 6 which is the limit for shelf life acceptance. The trends in hue angle values (Fig. 1.2) were similar to visual scores. The hue angle of treatments T1, T2, T3 and T4 did not change significantly even up to 22 days of storage. All potatoes under treatments T1, T2, T3 and T4 looked and smelled similar to freshly peeled potatoes up to a storage period of 28 days at 1°C.

This example was also able to demonstrate that coating alone can inhibit browning up to 5 days compared to 1 to 2 days with the control samples. Comparison of T6 with T5, T4 to T4 with T3, and T2 with T1 indicate that the levels of sodium acid pyrophosphate (SAPP) which is a chelating agent did not exhibit any additional or synergistic effect in conjunction with ascorbic and citric acid in inhibiting browning.

In summary, treatment T4 required the least concentration of anti-browning agents that could inhibit browning in peeled potatoes stored at 4 ± 0.5 °C for up to 22 days. This extension in shelf life is very significant compared to a shelf life extension of 7 days previously reported for potato strips dipped in 10% ascorbic acid solution, packaged under an aerobic atmosphere and stored at 5°C.

EXAMPLE 2

The main object of this experiment was to determine the shelf life of peeled potatoes prepared and packaged using a method which combines coating, anti-browning agents and a semi-permeable packaging. The effects of gas packaging on product quality were also evaluated in comparison with a passive generation of equilibrium modified atmosphere (as in Example 1). The treatments used in this example are given in Table 2.1 below.

Table 2.1

Treatment	Packaging	Storage Temperature	Anti-Browning Agent
1C	Air	1°C	None
1A	Air	1°C	Yes
1G	Gas	1°C	Yes
4C	Air	4°C	None
4A	Air	4°C	Yes
4G	Gas	4°C	Yes

Approximately 150g of Sebago potato tubers were hand-peeled and prepared as described in Example 1. The coating and anti-browning agents were applied in two stages: (1) Solution I was an alginate solution (2.8% w/v Manucol DM (Registered Trade Mark), Kelco); and (2) Solution II consisted of 2% ascorbic acid, 0.5% citric acid, and 2% calcium chloride (w/v). All solutions were prepared at room temperature and stored at 4 ± 0.5°C overnight. Each peeled potato tuber receiving the coating was immersed in Solution I for about 1-5 minutes, and allowed to drip, followed by immersion in Solution II which resulted in a clear homogenous coat over the entire surface of the potatoes. After draining in a colander, 6 peeled tubers were placed in a semi-permeable plastic bag (200 x 240 mm). Packages representing treatments 1A and 4A were manually heat sealed to simulate passive generation of equilibrium-modified atmospheres by the natural respiration of the produce. Gas packaged samples (treatments 4G and 1G) were prepared by subjecting each package to partial vacuum and gas flushing using a Freshpac Model AVS gas packaging equipment (Freshpac Machinery, NSW). An initial concentration of 30% CO_2 and 5% O_2 was attained in these gas-flushed samples. Additional treatments (4C and 1C) acting as the control samples were prepared by dipping the peeled potatoes in water followed by manual heat sealing using the same semi-permeable packaging material. Treated samples and contr ls were stored at either 4 ± 0.5 °C or 1 ± 0.5 °C for as long as 4 weeks.

Oxygen and carbon dioxide levels in the packages were measured by injecting 20 ml of gas sample drawn from the package into a "MAPtest 4000" gas analyser (HiTech Instruments, U.K.). The gas analyser uses a zirconia oxygen sensor and an infra-red carbon dioxide sensor. The accuracy of measurements is about ± 1 % of the reading.

Compression tests (Lloyd, Model 1000R, U.K, 100 N load cell, crosshead speed 20mm/min, 8mm diameter flat plunger) were performed on a flat surface of 8 randomly selected potatoes (coat removed). The maximum load encountered during a 3 mm penetration on the surface was taken as a measure of firmness or softness of the potatoes.

The pH of the solution and surface of the potatoes were monitored using either a Horiba pH meter (Model B112) or an Radiometer model PHM64.

Results and Discussion

Colour Changes

Storage at 1°C. Tables 2.2 and 2.3 below give a summary of visual evaluation and hue angle values computed from the CIELAB tristimulus data.

Table 2.2 - Colour Assessment of Peeled Potatoes Stored at 1°C

Treatment	Storage Days	Hue Angle	Visual Score	Comments
1C	0	101.4	10	Acceptable
1C	7	97.6	5	Browned, white lignin
1C	14	91.0	4	Extreme browning
1C	21	88.8	4	Extreme browning
1C	28	85.2	4	Extreme browning
1A	0	101.9	10	Acceptable
1A	7	102.2	9	Acceptable
1A	14	102.7	8	Acceptable
1A	21	102.5	8	Acceptable
1A	28	101.7	8	Acceptable
1G	0	101.7	10	Acceptable
1G	7	101.1	9	Acceptable
1G	14	103.1	8	Acceptable
1G	21	102.3	8	Acceptable
1G	28	102.8	8	Acceptable

Table 2.3 - Colour Assessment of Peeled Potatoes Stored at 4°C

Treatment	Storage Days	Hue Angle	Visual Score	Comments
4C	0	102.0	10	Acceptable
4C	7	91.7	5	Browned, white lignin
4C	14	88.5	4	Extreme browning
4C	21	84.8	4	Extreme browning
4C	28	83.0	4	Extreme browning
4A	0	102.0	10	Acceptable
4A	7	103.0	9	Acceptable
4A	14	102.8	8	Acceptable
4A	21	101.8	7	Acceptable
4A	28	101.1	5	Mould, yeasts growth
4G	0	102.0	10	Acceptable
4G	7	103.0	9	Acceptable
4G	14	103.0	8	Acceptable
4G	21	102.8	8	Acceptable
4G	28	103.7	5	Mould, yeasts growth

The results of visual observation indicate that whole peeled potatoes which were prepared and packaged using the developed system (1A and 1G) and stored at 1°C were visually acceptable even after 28 days. No off-odour was detected in the treated samples indicating the absence of anaerobic respiration. In comparison, the control samples (1C) that were dipped in water exhibited browning and white lignin formation within 2 days of storage at 1°C.

Computed hue angle values support the results of visual observations. Hue angle values of treated samples (1A and 1G) did not change significantly even after 28 days of storage at 1°C (see Table 2.2). In contrast hue angle values of the control sample decreased from 100 to 97° in just 4 days after storage at 1°C. The results of both visual and hue angle value indicate that gas packaging did not give any significant advantage compared to a passive method of equilibrium-modified atmosphere generation (1A). This could be due to the inability of CO_2 to remain in the package for a long period of time. CO_2 concentration in gas flushed packages decline from an initial 30% to less than 10% within 24h.

Storage at 4°C. The trends observed for samples stored at 4°C were similar to those for samples stored at 1°C (see Table 2.3). All treated samples did not exhibit browning during the entire duration of the storage. However, visual signs of mould and yeast growth were observed in treated samples after 28 days of storage at 4°C. This suggests that the maximum shelf life attainable in peeled potatoes is 28 days at 4 °C. This is a very significant extension in shelf life as the control untreated samples displayed a shelf life of only 3 days because of the development of enzymatic browning and white lignin formation on the surface of the potatoes.

Microbiology

Storage at 1°C. All treated samples (1A and 1G) were found to contain acceptable levels of microbial loads even after 28 days of storage at 1°C (see Table 2.4 below). Except for yeast and standard plate count (SPC), there was no significant increase in microbial loads during the entire duration of the experiment. The inhibition in microbial

growth could be due to the lowering of pH on the surface of the potatoes which was about 2.7 immediately after packaging (see Tables 2.6 and 2.7 below). In addition, both ascorbic acid and citric acid were reported to exhibit antimicrobial action in model system of peeled potatoes. The pH of Solution II at the start of the trial was about 2.0 (see Tables 2.8 and 2.9 below). Yeast which could survive low pH (> 1.5), increased from 4 cfu/cm^2 initially to 1.1 x 10^5 after 28 days. This yeast count is considered acceptable compared to the limit of 4 x 10^6 cfu/cm^2 prescribed by the French Standards.

Table 2.4 - Microbial Counts of Peeled Potatoes Stored at 1°C

Treatment	Storage Days	Yeast (cfu/cm^2)	Moulds (cfu/cm^2)	Aerobic Count (cfu/cm^2)	Anaerobic Count (cfu/cm^2)
1A	0	4	4	8	3
1A	7	3	3	22	3
1A	14	214	4	143	3
1A	21	4.9 x 10^3	3	328	328
1A	28	6.5 x 10^4	48	4.0 x 10^3	8
1G	0	4	4	8	3
1G	7	3	4	8	3
1G	14	11	8	10	3
1G	21	205	3	39	3
1G	28	4.2 x 10^4	43	4.2 x 10^3	1.0 x 10^3

Table 2.6 -Atmosphere Compositi n and pH of Samples Stored at 1°C

Treatment	Storage Days	Atmosphere (%)		pH	
		O_2	CO_2	Solution	Surface
1C	0	21.0	0.0	-	-
1C	7	7.6	3.2	-	-
1C	14	9.7	2.6	-	-
1C	21	4.2	3.2	-	-
1C	28	6.6	4.7	-	-
1A	0	21.0	0.0	2.0	2.8
1A	7	10.0	2.7	3.2	2.7
1A	14	11.0	1.8	3.4	3.6
1A	21	6.1	2.2	3.6	3.4
1A	28	5.9	3.4	3.7	3.7
1G	0	4.8	35.0	2.0	2.7
1G	7	10.0	3.7	3.2	2.4
1G	14	12.0	1.6	3.4	3.5
1G	21	7.0	2.0	3.5	3.2
1G	28	6.6	3.4	3.6	3.6

Table 2.7 -Atmosphere Composition and pH of Samples Stored at 4°C

Treatment	Storage Days	Atmosphere (%)		pH	
		O_2	CO_2	Solution	Surface
4C	0	21.0	0.0	-	-
4C	7	8.1	3.2	-	-
4C	14	5.5	3.8	-	-
4C	21	3.9	3.0	-	-
4C	28	4.3	3.5	-	-
4A	0	21.0	0.0	2.0	2.7
4A	7	10.8	3.0	3.1	2.8
4A	14	9.7	2.8	3.5	3.1
4A	21	6.2	2.9	3.7	3.6
4A	28	5.1	5.1	4.1	3.8
4G	0	6.0	31.0	2.0	2.7
4G	7	7.5	4.0	2.7	3.2
4G	14	10.1	2.6	3.4	-
4G	21	7.5	2.0	3.7	3.5
4G	28	4.3	4.9	3.9	3.8

Table 2.8 - Firmness Values of Peeled P tatoes Stored at 1°C

Treatment	Storage Days	Firmness (N)	
		Mean	Deviation
1A	0	40.5	6.3
1A	7	45.1	6.1
1A	14	56.0	4.1
1A	21	41.8	6.9
1A	28	40.3	8.9
1G	0	40.3	8.9
1G	7	41.8	3.1
1G	14	53.9	5.4
1G	21	39.0	5.9
1G	28	42.9	4.0

Table 2.9 - Firmness Values of Peeled Potatoes Stored at 4°C

Treatment	Storage Days	Firmness (N)	
		Mean	Deviation
4A	0	40.5	6.3
4A	7	44.3	3.5
4A	14	40.0	3.0
4A	21	41.3	3.9
4A	28	41.2	5.5
4G	0	40.3	6.3
4G	7	40.5	3.1
4G	14	40.4	5.3
4G	21	40.5	6.3
4G	28	42.5	5.5

Storage at 4°C. All the microbial counts from treated potato samples stored at 4°C were within acceptable limits. The changes in microbial counts were similar to those treated samples stored at 1°C. However, the magnitude of increase is slightly higher in yeasts and aerobic plate counts (see Table 2.5 below).

Table 2.5 - Micr bial Counts of Peeled P tatoes Stored at 4°C

Treatment	Storage Days	Yeast (cfu/cm^2)	Moulds (cfu/cm^2)	Aerobic Count (cfu/cm^2)	Anaerobic Count (cfu/cm^2)
4A	0	4	3	15	3
4A	7	3	4	13	3
4A	14	3.1×10^3	3	1.3×10^3	70
4A	21	4.8×10^4	4	9.9×10^3	374
4A	28	4.0×10^5	53	1.2×10^5	52
4G	0	4	3	10	3
4G	7	4	3	18	3
4G	14	186	3	61	4
4G	21	3.3×10^4	3	2.0×10^4	3
4G	28	7.5×10^4	10	9.6×10^4	3

Texture

The treatments and storage period used in this example had no effect on firmness of raw potatoes as measured by a compression test employed in this example (see Table 2.9). The treated potatoes looked similar to freshly peeled potatoes.

EXAMPLE 3

The object of this experiment was to compare the method of combining coating and anti-browning agents with the use of sodium metabisulfite in preserving the fresh appearance of peeled potatoes.

150g of Coliban potatoes were hand-peeled with a sharp knife and temporarily stored in water for about 10-30 minutes. Peeled potatoes were divided into the following treatments: (1) "Coated" - samples coated with combinations of alginate and anti-browning agents; (2) "Sulfited" - samples dipped in sodium metabisulfite, and (3) "Control" - samples dipped in water.

Coated samples were prepared and packaged as described in Examples 1 and 2. Each peeled potato was immersed in Solution I which was an alginate solution (2.8% w/v Manucol (Registered Trade Mark), Kelco) for about 1-5 minutes, allowed to drip and then immersed in Solution II which resulted in a clear homogenous coat over the surface of the potatoes. Solution II consisted of 2% ascorbic acid, 0.5% citric acid and 2% calcium chloride (w/v). After draining the excess solution, 6 coated tubers were placed in a semi-permeable plastic bag (200 x 240mm). All the plastic bags were heat sealed prior to storage at 8 ± 0.5°C.

Sulfited samples were prepared by immersing the peeled potatoes in 1% solution of sodium metabisulfite for 2 minutes. Tubers were drained for 2-5 minutes, and 6 tubers were vacuum sealed using a Webomatic vacuum packaging machine (Model E50G) set at -1.0 bar. The plastic bags used for vacuum packaging were standard Cryovac barrier bags.

Control samples were dipped in water for about 2 minutes. After draining the excess water, 6 tubers were placed in plastic bags and heat sealed. The samples were placed at 8 ± 0.5°C.

Quality changes (i.e. colour and microbial counts) were monitored as described in Examples 1 and 2.

Results and Discussion

The results of the test are shown in Tables 3.1 and 3.2 below.

Table 3.1 - Colour Assessment of Peeled Potatoes Stored at 8°C

Treatment	Storage Days	Hue Angle	Visual Score	Comments
Control	0	99.1	10	Acceptable
Control	3	91.8	5	Brown spots
Control	6	88.5	4	Extreme browning
Control	10	86.9	4	Extreme browning
Control	14	83.6	4	Extreme browning
Control	21	-	-	
Sulfited	0	99.2	10	Acceptable
Sulfited	3	99.0	8	Slight off-odour
Sulfited	6	98.8	6	Soft, loss of vacuum
Sulfited	10	99.2	5	Very soft surface
Sulfited	14	99.2	4	Extremely soft
Sulfited	21	-	-	Not tested
Coated	0	99.3	10	Acceptable
Coated	3	99.8	9	Acceptable
Coated	6	99.8	8	Acceptable
Coated	10	100.8	8	Acceptable
Coated	14	99.2	8	Acceptable
Coated	21	-	5	Mould and yeasts growth

Table 3.2 - Microbial Counts of Peeled Potatoes St red at 8°C

Treatment	Storage Days	Yeasts (cfu/cm^2)	Moulds (cfu/cm^2)	Lactobacilli (cfu/cm^2)	Clostridia (cfu/cm^2)
Control	0	<50	50	<50	<4
Control	3	<50	<50	-	-
Control	6	140	<50	-	-
Control	10	-	-	-	-
Control	14	-	-	-	-
Sulfited	0	<50	<50	<50	<4
Sulfited	3	<50	<50	-	-
Sulfited	6	50	<50	-	-
Sulfited	10	150	100	-	-
Sulfited	14	<50	<50	1.8×10^7	<4
Coated	0	<50	<50	<50	<4
Coated	3	<50	<50	-	-
Coated	6	60	<50	-	-
Coated	10	3.6×10^3	<500	-	-
Coated	14	5.7×10^4	<50	<50	<4

As the information in Tables 3.1 and 3.2 clearly shows, it is possible to store peeled potatoes for at least 14 days at 8 ± 0.5°C without using sodium metabisulfite. After 14 days of storage at 8°C, coated potatoes looked and smelt like freshly peeled potatoes. There was no significant colour change in the coated potatoes as indicated by hue angle values (see Table 3.1). The shelf life of coated potatoes was terminated when yeast and mould growth became visible on the 21st day of storage. Yeast was the most dominant organism present in coated potatoes. As expected, it was *Lactobacilli* that dominated the microflora of vacuum packaged sulfited potatoes. *Lactobacilli* is known to grow under anaerobic conditions in vacuum packaged products.

In sulfite-vacuum packaged potatoes, the shelf life was limited to 6 to 10 days because of the development of off-odour, loss of vacuum and considerable softening of the potato surface. On the 10th day of storage, the sulfite potatoes were very soft and slimy, and therefore unacceptable to consumers. Similar undesirable changes in potato strips and whole peeled potatoes have been previously reported. Surface softening and off-odour development could be due to sulfur dioxide. However, the mechanism causing

this softening is still unknown. Softening could also be due to anaerobic fermentation and/or pectinolytic activity of *Lactobacilli* which is the most dominant organism in vacuum packaged potatoes.

EXAMPLE 4

The object of this experiment was to determine the individual and synergistic effects of a selected mixture of anti-browning agents and sodium alginate coating in inhibiting enzymatic browning in raw peeled potatoes.

Approximately 8 kg of Sebago potatoes each weighing about 150g were peeled using an abrasive peeler (P102 Peeler by Pelatori Polivalenti of Italy). Peeled potatoes were washed using tap water and divided into 4 lots corresponding to the treatments shown in Table 4.1 below. The vegetable gum (coating) and anti-browning agents were applied in two stages as described in Example 1. After draining in a colander, 4 peeled potatoes were placed in semi-permeable polyethylene blend plastic bag (175 x 190 mm). Preliminary work suggested that this packaging film would produce a useful aerobic equilibrium-modified atmosphere of about 2-10% oxygen. All plastic packages were heat sealed using a manual sealer (Venus Model VH400). An additional treatment (T1) which acted as a control was prepared by dipping the peeled potatoes in water. There were 4 replications per treatment. All samples were stored at 4±0.5°C for 21 days.

Table 4.1 - Treatments to assess effects f c ating, anti-browning mixture and their combinations

Treatment	Ascorbic Acid (%)	Citric Acid (%)	Sodium Alginate* (%)
T_1: Control	-	-	-
T_2: Anti-browning solution	2	0.5	-
T_3: Coat only	-	-	2.8
T_4: T_2 & T_3	2	0.5	2.8

*Manucol DM (Kelco), set by 1.5% calcium chloride in Solution II.

Treatment effectiveness was evaluated by measuring colour changes at the peeled surface of treated and control samples during storage. Colour changes on surface was measured as described in Example 1. A subjective visual evaluation was also conducted to assess the change in colour during storage. The scoring system described in Table 1.2 of Example 1 was used in this example.

Results and Discussion

Table 4.2 below shows the changes in hue angle, "L" values, and visual score during a 3 week period at 4°C. Both hue angle and "L" decrease during storage as a direct result of enzymatic browning on peeled potatoes prepared by treatments T_1, T_2, and T_3. The combination of a vegetable gum coating and mixture of anti-browning agents (T_4) did not result in any significant reduction in both "L" and hue angle values indicating maintenance of the original colour of the potatoes. Previous tests have shown that hue angle is the "best" indicator of enzymatic browning on the surface of peeled potatoes. Generally, a 7° reduction in the original value of hue angle is considered unacceptable.

Table 4.3 below gives a summary of shelf-life values of peeled potatoes prepared by various treatments. Results from this table show that dipping of abrasively-peeled potatoes in a solution of 2% ascorbic acid and 0.5% citric acid (T_2) did not result in any extension in shelf-life compared to those samples dipped in water (T_1, control treatment). Mixtures of ascorbic acid and citric acid are generally recommended to prevent enzymatic browning in cut or damaged fruit and vegetables.

The application of sodium alginate coating on peeled potatoes was able to give an additional 3 days shelf-life compared with control samples. This result indicates that a coating alone can be a potential tool in extending the shelf-life of peeled potatoes. The potential of a vegetable gum coating was best illustrated by treatment T4 which combined the gum coating and the anti-browning mixture. Using this approach, enzymatic browning was inhibited and shelf-life of peeled potatoes was extended up to 21 days. This result suggests a synergism between the use of coating and the mixture of ant-browning agents since adding the shelf-life values by the use of coating alone (T3) and anti-browning mixture (T2) would give only 11 days. The extension of shelf-life up to 21 days instead of 11 days strongly suggest synergism between the use of coating and mixtures of anti-browning agents.

Table 4.2 - Colour assessment of peeled potatoes prepared under vari us c nditions

Treatment	Storage days	Hue Angle	"L" value	Visual score	Comments
T1:	0	99.7	74.5	10	Acceptable
	7	91.7	71.7	4	Unacceptable
Control	14	88.9	70.4	4	Unacceptable
	21	NT*	NT*	NT*	-
T2:	0	99.7	74.9	10	Acceptable
	7	86.9	70.8	4	Unacceptable
Anti-	14	84.1	70.3	4	Unacceptable
browning	21	NT	NT	NT	-
solution					
T3:	0	96.3	63.6	10	Acceptable
	7	91.2	64.6	6	Marginally acceptable
Coat only	14	87.0	64.9	4	Unacceptable
	21	NT	NT	NT	-
T4:	0	100.8	67.6	10	Acceptable
	7	103.1	68.8	10	Acceptable
T2 & T3	14	104.7	69.9	9	Acceptable
	21	104.7	70.8	8	Acceptable

*NT - not tested

Table 4.3 - Summary of shelf-life values of peeled potat es prepared by dipping in anti-browning solution, coating, and their combinati n

Treatment	Shelf-life (days)
T1: Control	4
T2: Anti-browning solution	4
T3: Coat only	7
T4: T2 & T3	21

EXAMPLE 5

The object of this experiment was to compare the effectiveness of various solutions of anti-browning agents that included erythorbic acid, ascorbic acid and citric acid. Erythorbic acid is a cheaper alternative to ascorbic acid.

Approximately 8 kg of Sebago potatoes each weighing about 150g were peeled using an abrasive peeler (P102 Peeler by Pelatori Polivalenti of Italy). Peeled potatoes were washed using tap water and divided into 5 lots corresponding to the treatments shown in Table 5.1 below. The vegetable gum (coating) and anti-browning agents were applied in two stages: (1) Solution I contained 2.8% vegetable gum (sodium alginate Manucol DM, Kelco); and (2) Solution II was a combination of anti-browning agents (e.g. AB1, AB2, or plain water). All solutions were prepared at room temperature and stored at 4°C overnight. Each peeled potato receiving the vegetable gum coating was immersed into Solution I for about 5 minutes, and allowed to drip for about 20 seconds, followed by immersion into Solution II which resulted in a clear homogenous coat/film over the entire surface of the potatoes. It took about 10-20 minutes to complete the second immersion. After draining in a colander, 4 peeled potatoes were placed in semi-permeable polyethylene blend plastic bag (175 x 190 mm). Preliminary work suggested that this packaging film would produce a useful aerobic equilibrium-modified

atmosphere of about 2-10% oxygen. All plastic packages were heat sealed using a manual sealer (Venus Model VH400). An additional treatment (T1) which acted as a control was prepared by dipping the peeled potatoes in water. There were 4 replications per treatment. All samples were stored at 4±0.5°C for as long as 21 days.

Table 5.1 - Treatments for whole peeled potatoes

Treatment	AA* (%w/v)	EA* (%w/v)	CA* (%w/v)	CC* (%w/v)	Vegetable Gum
T1: Control					
T2: AB1	2	-	0.5	1.5	-
T3: AB2	-	2	0.5	1.5	-
T4: Gum+T2	2	-	0.5	1.5	2.8@
T5: Gum+T3	-	2	0.5	1.5	2.8@

*AA-Ascorbic acid, EA-Erythorbic acid, CA-citric acid, CC-Calcium chloride in Solution II.

@Vegetable gum was present only in the first dip (Solution I).

Treatment effectiveness was evaluated by measuring colour changes at the peeled surface of treated samples and control during storage. To measure colour objectively, the CIELAB's "*L*" (light-dark), "*a*" (red-green) and "*b*" (yellow-blue) for randomly selected surface areas were measured using a Minolta Chroma meter, Model CR300 with a 8 mm specimen port. To evaluate the change in colour, hue angle was also calculated from the tristimulus data ("a" and "b"). Hue angle values of 0°, 90°, 180° and 270 indicate red, yellow, green, and blue, respectively. Hue angle values close to 90° indicate more browning. A 7° (degrees) reduction in hue angle value based from the original (day 0) reading is generally considered unacceptable in appearance.

A subjective visual evaluation was also conducted to assess the change in colour

during storage. The scoring system described in Table 1.2 of Example 1 was used to subjectively assess the visual acceptability of fresh peeled potatoes. A colour score of "5" and below was considered unacceptable.

Results and Discussion

Tables 5.2 and 5.3 below clearly demonstrate that combination of vegetable gum coating and anti-browning agents (T4 and T5) could significantly inhibit enzymatic browning and extend the shelf-life of peeled potatoes. Shelf-life values in Table 5.3 below indicate that a significant extension of shelf-life values can be obtained if the coating is combined with selected anti-browning agents (T4 and T5). Shelf-life was extended up to 700%, from 3 days up to 21 (treatment T5 compared to treatments T2 or T3). Erythorbic acid was found to be a better and inexpensive alternative to ascorbic acid (Vitamin C).

In summary, this example was able to demonstrate the synergistic effects of applying anti-browning agents with vegetable gum, thereby prolonging the shelf-life of peeled potatoes up to 21 days compared to 1 day with control samples and 3 days with anti-browning agents only.

Table 5.2 - Col ur assessment of peeled potatoes at 4°C

Treatment	Storage days	Hue Angle	"L" value	Visual score	Comments
T1: Control	0	100.1	71.6	10	Acceptable
	4	78.5	64.86	4	Unacceptable
	8	74.4	5.9	4	Unacceptable
	14	NT*	NT*	NT*	-
T2: AB1	0	99.7	76.9	10	Acceptable
	4	88.4	72.1	5	Unacceptable
	8	81.7	68.9	4	Unacceptable
	14	NT	NT	4	-
T3: AB2	0	99.7	76.9	10	Acceptable
	4	92.1	74.1	5	Unacceptable
	8	85.1	69.9	4	Unacceptable
	14	NT	NT	NT	-
T4: Gum+T2	0	98.4	70.1	10	Acceptable
	4	99.7	73.7	9	Acceptable
	8	100.2	73.9	8	Acceptable
	14	95.6	73.7	7	Acceptable, slight browning
T5: Gum+T3	0	99.3	70.9	10	Acceptable
	4	101.2	73.9	10	Acceptable
	8	100.0	74.6	9	Acceptable
	14	97.1	72.3	8	Acceptable

*NT - not tested

Table 5.3 - Shelf-life of peeled potat es stored at 4°C

Treatment	Shelf-life (days)
T1: Control	1
T2: AB1	3
T3: AB2	3
T4: Gum + AB1	14
T5: Gum + AB2	21

EXAMPLE 6

The object of this experiment was to determine the effectiveness of the combination of a vegetable gum coating and anti-browning agents in preserving the appearance of steam peeled potatoes.

Approximately 40 kg steam-peeled Russet Burbank potatoes were taken from McCains' Ballarat Plant. These Russet Burbank potatoes obtained from the same batch were immediately immersed in cold water inside barrier plastic bags and transported to the testing area which took about 2 hours. Before testing, steam-peeled potatoes were divided into 3 lots corresponding to the treatments shown in Table 6.1 below. The vegetable gum (coating) and anti-browning agents were applied in two stages as described in Example 1.

Calcium chloride was added in the solution of ascorbic acid and citric acid in treatment T_2 because calcium chloride may contribute in preventing discolouration in steam peeled potatoes. The type of discolouration commonly found on heat treated potatoes is a black discolouration commonly called "after cooking darkening". The rate of darkening on heated potatoes is generally faster than conventional enzymatic browning found in mechanically peeled potatoes.

After draining in a colander, 4 peeled potatoes were placed in semi-permeable polyethylene blend plastic bag. All plastic packages were heat sealed using a manual sealer (Venus Model VH400). There were 4 replications per treatment. All samples were stored at 4±0.5°C.

Treatment effectiveness was evaluated by measuring colour changes at the peeled surface of treated and control samples during storage. Colour changes on surface was measured as described in Example 1.

A subjective visual evaluation was also conducted to assess the change in colour during storage. The scoring system described in Table 1.2 of Example 1 was used in this example.

Table 6.1 - Treatments used for steam peeled potatoes

Treatment	Anti-browning Solution			Sodium Alginate Coating* (%)
	Ascorbic Acid (%)	Citric Acid (%)	Calcium Chloride (%)	
T1: Control	-	-	-	-
T2: Anti-browning solution	2.0	0.5	1.5	-
T3: Coat & T2	2.0	0.5	1.5	2.8

*Manucol DM (Kelco)

Results and Discussion

Table 6.2 below shows the changes in hue angle, "L" values, and visual score reflecting the changes in colour of steam peeled potatoes during a 2 week period at 4°C. A reduction in hue angle and "L" values represents an increase in dark discolouration on the surface of the potatoes. Table 6.3 below gives a summary of shelf-life values of steam peeled potatoes in this experiment.

Steam peeled potatoes used in this experiment were observed to develop dark discolouration within an hour after exposure to ambient air. The rate and amount of dark discolouration was found to be more compared to enzymatic browning normally found in mechanically peeled potatoes. Control samples dipped in water were found to have a shelf-life of less than a day because of excessive darkening of steam peeled potatoes.

In comparison, dipping steam peeled potatoes in the mixture of ascorbic acid, citric acid and calcium chloride (T2) was able to slow down the rate of darkening up to a period of about 3-4 days (Table 6.2).

The preservation system (T3) was found to be very effective in inhibiting darkening of steam peeled potatoes up to a period of 2 weeks. During a 2 week period, no significant change in colour was observed in coated potatoes as indicated by hue angle, "L" values and visual scores. This result confirmed the effectiveness of the developed preservation system that uses the vegetable coating with selected anti-browning agents on steam peeled potatoes. Longer shelf-life values may be obtained by the use of coating if potatoes can be treated immediately after steam peeling. The delay in applying the coating in this experiment was about 4 hours.

Table 6.2 - Colour assessment of peeled potatoes prepared under various conditions

Treatment	Storage days	Hue Angle	"L" value	Visual score	Comments
T1:	0	108.6	71.6	10	Acceptable
	7	85.6	58.8	3	Unacceptable, dark discolouration
Control	14	NT*	NT*	NT*	Unacceptable
T2:	0	108.6	71.6	10	Acceptable
	7	98.9	66.7	4	Unacceptable, dark discolouration
Anti-browning solution	14	NT	NT	NT	Unacceptable
T3:	0	110.8	72.1	10	Acceptable
	7	110.8	72.1	10	Acceptable, no discolouration
Coat + T2	14	108.4	72.3	9	Acceptable, no discolouration

*NT - not tested

Table 6.3 - Summary of shelf-life values of steam peeled potatoes

Treatment	Shelf-life (days)
T1: Control	0
T2: Anti-browning solution	4
T3: Coat & T2	14

EXAMPLE 7

Development of white material on the surface of abraded carrots generally limit the acceptance and shelf-life of this product. This white discolouration commonly referred as "white-blush" may be due to the formation of lignin as a wound barrier and/or dehydration of abraded surfaces. Studies have indicated that certain key enzymes seemed to be associated with lignin formation, some of which were: phenylalanine lyase, tyrosine ammonia lyase, cinnamic acid-4-hydroxylase, caff ic acid O-methyl transferase, 5-hydroxyferulic acid O-methyl transferase and peroxidase. Surface discolouration may be controlled by hot acidic or basic dip solution. Ideal treatment would inactivate enzymes involved in development of surface discolouration, but not affect colour, texture or microbiological quality of the product. The use of vegetable gum coating with citric acid may be more practical "non-thermal" method of slowing down white discolouration in peeled carrots.

The objective of this study was to determine the effectiveness of a process that combined coating and acidulant to preserve the appearance of abrasive-peeled carrots. The effectiveness of the novel process was compared with an acidic dip treatment without coating, and a water-dip treatment acting as control.

Carrots were cut uniformly into batons and mechanically-peeled by an abrasive peeler to simulate commercial operation. Peeled carrot batons were washed using cold water and divided into 3 lots corresponding to the treatments shown in Table 7.1 below. The vegetable gum coating (T) with citric acid and calcium chloride were applied in two stages: (1) Solution I contained 3% sodium alginate solution; and (2) Solution II was a combination of citric acid and calcium chloride. Calcium chloride was added in Solution II as the firming agent of sodium alginate. All solutions were prepared at room temperature and stored at 4°C overnight. Each peeled carrot baton receiving the alginate coating (T3) was immersed into Solution I for about 5 minutes. Excess sodium alginate solution was removed by draining the batons for about 5 minutes, followed by immersion into Solution II which resulted in a thin clear homogenous coat/film over the entire surface of the batons. It took about 10 minutes to complete the second

immersion. After draining in a colander, 4 peeled batons were placed in semi-permeable polyethylene blend plastic bag. All plastic packages were heat sealed using a manual sealer (Venus Model VH400). There were 4 replications per treatment. All samples were stored at 4±0.5°C.

An additional treatment (T1) which acted as a control was prepared by dipping the peeled carrot batons in water for about 30 seconds. Similarly, carrot batons corresponding to acidic treatment (T2) were dipped in citric acid solution for 30 seconds.

Treatment effectiveness was evaluated by measuring colour changes at the peeled surface of treated samples and control during storage. To measure colour objectively, the CIELAB's "*L*" (light-dark), "*a*" (red-green) and "*b*" (yellow-blue) for randomly selected surface areas were measured using a Minolta Chroma meter, Model CR300 with a 8 mm specimen port. Since the most pronounced change in appearance in peeled carrot is the development of white material on the cut surfaces, individual "L", "a", and "b" values were converted into "whiteness index" (W.I.) values. Whiteness index was computed as follows: $W.I. = 100 - \{(100-L)^2 + a^2 + b^2\}^{1/2}$.

Table 7.1 - Treatments for abrasive-peeled carrot baton

Treatment	Coating	Solution II
T1	None	Water
T2	None	2% Citric acid
T3	3% Sodium alginate*	2% Citric acid

*Firmed by 1% calcium chloride added in Solution II

Results and Discussion

The results of the test are shown in Tables 7.2, 7.3 and 7.4 below.

White discolouration

The use of vegetable gum coating incorporating citric acid and calcium chloride effectively retarded development of surface discolouration on minimally processed carrot batons (Fig. 3 and Table 7.2). Elevated whiteness index (W.I) and "L" values indicate increased whitening while low values indicate darker orange appearance. Coated carrot batons retained acceptable bright orange appearance throughout the test. A large increase in surface discolouration occurred on control (water-dipped) samples during storage. The peak in white discolouration was observed at day 8.

Based on visual observations, water dipped carrots became unacceptable after 3 days and acidic dipped sample after 8 days of storage (Table 7.3). In contrast, coated peeled carrot batons were acceptable up to 28 days.

In summary, coating the carrots in conjunction with the use of citric acid can extend the shelf-life of peeled carrot batons by inhibiting white discolouration up to 28 days. This was estimated to be about 900% extension in shelf-life compared to water-dipped samples and about 350% extension compared to acidic dip treatment.

Microbiological quality

The use of vegetable gum coating in conjunction with the use of 2% citric acid in peeled carrot batons have also the added benefit of improved microbiological quality compared to simple acidic dip and water-dipping (Table 7.4). The vegetable gum coating as shown by the results in Table 7.4 was able to produce the lowest and acceptable levels of microbial load even after 21 days of storage at 4°C.

Table 7.2 - Colour assessment of carrot batons stored at 4°C

Treatment	Storage days	Whiteness Index	"L"	Comments
T1: Control	0	36.8	56.6	Acceptable
	1	47.8	62.9	White discolouration, acceptable
	3	48.0	61.5	Unacceptable, white discolouration
	8	51.2	64.7	Unacceptable
	16	51.4	64.2	Unacceptable
	21	51.6	62.9	Unacceptable
	28	-	-	NT@
T2:	0	36.8	56.6	Acceptable
	1	36.8	56.6	Acceptable
	3	36.7	56.2	Acceptable
	8	43.6	59.6	Marginally acceptable, white lignin
	16	46.8	60.7	Unacceptable
	21	47.6	60.7	Unacceptable
	28	48.9	63.7	Unacceptable
T3	0	36.8	56.6	Acceptable
	1	37.5	57.3	Acceptable
	3	39.4	57.3	Acceptable
	8	41.7	56.8	Acceptable
	16	41.8	57.5	Acceptable
	21	44.6	59.6	Acceptable
	28	46.6	62.2	Acceptable, slightly dry

@NT - not tested

Table 7.3 - Summary f shelf-life values of peeled carrot bat ns

Treatments	Shelf-life (days)
T1 (Control)	3
T2	8
T3	28

Table 7.4 - Comparison of carrot baton microbiological population after 21 days at 4°C

Microbial count	T1: Control	T2: Acid only	T3: C ated
Total count	290,000	13,000	138
Pseudomonas	37,000	140	138
Enterobacteriaceae	15,000	3,200	50
Coliform	1,800	1,300	17
Aeromonas	22,000	510	13
Lactic acid bacteria	1,300	190	25
Yeast	10	170	13

EXAMPLE 8

The object of this experiment was to determine the effectiveness of the combination of vegetable gum coating and anti-browning agents in preserving the appearance of whole onions with top, tail and outer peel removed.

Thirty-six (36) onions were prepared manually by cutting their tops and tails prior to removing the outer cured peel. All onions were washed with water for about 30 seconds. After draining, peeled onions were divided into 3 lots corresponding to the treatments shown in Table 8.1 below. The vegetable gum (coating) and anti-browning agents were applied in two stages as described in Example 1.

After draining in a colander, 4 peeled onions were placed in semi-permeable polyethylene blend plastic bag. All plastic packages were heat sealed using a manual sealer. There were 3 replications per treatment. All samples were stored at 4±0.5°C.

Table 8.1 - Treatments used for peeled onions

Treatment	Anti-browning Solution			Sodium Alginate Coating*
	Ascorbic Acid (%)	Citric Acid (%)	Calcium Chloride (%)	(%)
T1: Control	-	-	-	-
T2: Anti-browning solution	2.0	0.5	1.5	-
T3: Coat & T2	2.0	0.5	1.5	2.8

*Manucol DM (Kelco)

Treatment effectiveness was evaluated by measuring colour changes at the cut top and tail surfaces of the whole onions. Colour changes on top and tail surfaces were measured using a Minolta Chroma meter, Model CR300 with a 8mm specimen port. Since the most pronounced change in appearance in peeled whole onion was observed to be the development of white material on the cut surfaces, individual "L", "a", and "b" values were converted into "whiteness index" (W.I.) values. Whiteness index was computed as follows: $W.I. = 100 - \{(100-L)^2 + a^2 + b^2\}^{1/2}$.

Results and Discussion

Preliminary experiments with peeled onions (with tops and tails removed by knife) indicated that the development of material that forms on the cut surfaces was limiting the visual acceptance of this product during storage. The formation of white material was similar to white lignin formation in peeled carrots. Dehydration of the cut surfaces probably contributed also to the appearance of white discolouration.

Table 8.2 below shows the changes in whiteness index values (W.I.), "L" values, and visual observations on peeled onions stored at 4°C. High whiteness index values indicate increase in white material formation. Similarly, increase in "L" values indicate whitening on the measured surfaces. A graph of whiteness index values as a function of the storage period is shown in Fig. 4. The graph clearly demonstrates that the combination of sodium alginate coating and mixture of ascorbic acid and citric acid can maintain the whiteness index value up to 21 days. In comparison, control treatment (T1) and acidic dipped treatment (T2) increased in whiteness index values immediately during storage. The peak in white discolouration occurred after 14 days of storage in both treatments. Coated onions exhibited a very slight increase in whiteness index which was acceptable during the 3 week period.

A summary of shelf-life values are given in Table 8.3 below. This example have demonstrated that the developed preservation system for peeled potatoes can also prevent colour changes and extend the shelf-life of peeled onions.

Table 8.2 - C lour assessment of peeled onion prepared under various conditions

Treatment	Storage days	W. I.@	"L" value	Comments
T1:	0	70.3	74.7	Acceptable
	4	74.0	78.3	Acceptable, white discolouration
Control	7	74.1	78.1	Unacceptable, white & dry
	9	74.6	78.9	Unacceptable, white & dry
	11	74.8	79.1	Unacceptable, white
	14	75.1	79.1	Unacceptable
	21	74.6	78.9	Unacceptable
T2:	0	69.1	72.8	Acceptable
	4	69.6	72.3	Acceptable but dry
Anti-browning	7	72.2	75.4	Acceptable, white & dry
solution	9	72.3	75.2	Acceptable, white & dry
	11	72.5	75.8	Acceptable, white & dry Unacceptable,
	14	73.6	76.9	white & dry
	21	73.6	77.7	Unacceptable
T3:	0	66.9	70.5	Acceptable
	4	65.7	69.4	Acceptable
Coat + T2	7	66.4	69.9	Acceptable, moist
	9	67.5	71.2	Acceptable, moist
	11	65.3	68.8	Acceptable, moist
	14	67.8	70.9	Acceptable, slightly white
	21	67.9	70.9	Acceptable, slightly dry & white

@Whiteness index

Table 8.3 - Summary of shelf-life values of peeled oni n

Treatment	Shelf-life (days)
T1: Control	7
T2: Anti-browning solution	11
T3: Coat & T2	21

EXAMPLE 9

The object of this experiment was to evaluate the effectiveness of vegetable gum coatings based on agar or "agar-agar" solely or in combination with sodium alginate.

The above examples have shown the effectiveness of combining sodium alginate coating with selected mixtures of anti-browning agents. In some situations, a coating that dissolves in hot water (i.e. thermo-reversible) could be an advantage. While coatings based on sodium alginate are mostly thermo-stable, coatings based on agar would be mainly thermo-reversible. Therefore, this study was conducted to investigate the levels of agar solely or in combination with sodium alginate that could preserve the colour and appearance of raw peeled potatoes.

Sebago potatoes each weighing about 150g were peeled using an abrasive peeler (P102 Peeler by Pelatori Polivalenti of Italy). Peeled potatoes were washed using tap water and divided into 8 lots corresponding to the treatments shown in Table 9.1 below. The agar-based coating and anti-browning agents were applied in two stages: (1) Solution I was warm agar solution (60°C); and (2) Solution II was a combination of anti-browning agents (ascorbic acid, citric acid and calcium chloride).

Each peeled potato receiving the agar-based coating was immersed into warm Solution I (about 60°C) for about 30 s, followed by immersion into Solution II at a temperature of about 15°C. The agar coated potatoes were allowed in Solution II for

about 15 minutes. After draining in a colander, 4 peeled potatoes were placed in semi-permeable polyethylene blend plastic bag (175 x 190 mm). All plastic packages were heat sealed using a manual sealer (Venus Model VH400). An additional treatment (T1) which acted as a control was prepared by dipping the peeled potatoes in water. There were 3 replications per treatment. All samples were stored at 4±0.5°C.

Treatment effectiveness was evaluated by measuring colour changes at the peeled surface of treated samples and control during storage. To measure colour objectively, the CIELAB's "*L*" (light-dark), "*a*" (red-green) and "*b*" (yellow-blue) for randomly selected surface areas were measured using a Minolta Chroma meter, Model CR300 with a 8 mm specimen port. To evaluate the change in colour, hue angle was also calculated from the tristimulus data ("a" and "b"). Hue angle values of 0°, 90°, 180° and 270 indicate red, yellow, green, and blue, respectively. Hue angle values close to 90° indicate more browning. Generally, a 7° (degrees) reduction in hue angle corresponds to the end of acceptable shelf-life.

A subjective visual evaluation was also conducted to assess the change in colour during storage. A scoring system described in Table 1.2 of Example 1 was also used to subjectively assess the visual acceptability of fresh peeled potatoes. A colour score of "6" was considered marginally acceptable. End of shelf-life corresponds to a visual score of 5.

Table 9.1 - Treatments for whole peeled potatoes prepared using c atings based on agar

Treatment	Solution I (coating)		Solution II		
	Agar@ (%)	Sodium Alginate* (%)	Ascorbic Acid (%)	Citric Acid (%)	Calcium Chloride (%)
T1 (Control)	-	-	-	-	-
T2 (no coat)	-	-	2	0.5	1.0
T3	1.0	-	2	0.5	1.0
T4	2.0	-	2	0.5	1.0
T5	3.0	-	2	0.5	1.0
T6	1.0	0.5	2	0.5	1.0
T7	2%	0.5	2	0.5	1.0
T8	2%	1.0	2	0.5	1.0

*Manucol DH (Kelco)

@Agar or Agar-Agar (750 bloom, Langdon and Company)

Results and Discussion

The results of the test are shown in Tables 9.2 and 9.3 below.

Based on the results of Tables 9.2 and 9.3, thermo-reversible agar coatings can be an alternative to sodium alginate coatings in extending the shelf-life of peeled potatoes. Results of treatment T4 have shown that the application of 2% agar in

conjunction with 2% ascorbic acid, 0.5% citric acid, and 1.0% calcium chloride can extend the shelf-life of raw peeled potatoes against enzymatic browning up to 3 weeks at 4°C. Similar effectiveness can be attained by the application of 3% agar as illustrated by treatment T5. Coatings from T3, T4, and T5 are fully thermo-reversible in boiling water. In situations where less visible coating is required, the use of 1% agar that would give a shelf-life of about 8 days may be acceptable. This treatment T3 is deemed to be the minimum required level of agar to have any desirable effect on shelf-life.

In cases where extra coating strength is required, the addition of sodium alginate with agar may be necessary. The results of treatments T6, T7, and T8 have shown that blends of agar and sodium alginate offered about the same magnitude of effectiveness as indicated by their shelf-life values (Table 9.3) and various indices of colour changes (Table 9.2). These blends of agar and alginate coatings would normally turn into small fragments during boiling.

In summary, the results of this test suggest that an agar concentration as low as 2% (T4), and a blend of 1% agar with 0.5% alginate (T6) could deliver similar shelf-life values obtained by the use of "pure" sodium alginate coatings. Higher concentration of agar or blends with sodium alginate can also offer the same effectiveness as shown by treatments T4 to T8.

Table 9.2 - Summary of visual appearance f raw peeled p tatoes c ated with agar

Treatment	Storage days	Hue Angle	"L" value	Visual score	Comments
T1: Control	0	94.4	74.5	10	Acceptable
	5	85.5	71.7	4	Unacceptable
	8	82.6	71.2	4	Unacceptable
	16	78.8	69.5	3	Unacceptable
	21	-	-	-	NT*
T2:	0	100.9	75.4	10	Acceptable
	5	89.4	70.1	5	Marginally acceptable, browned surface
	8	90.3	72.0	4	Unacceptable
	16	81.2	66.7	-	NT
	21	-	-	-	NT
T3	0	100.5	74.6	10	Acceptable
	5	93.4	72.2	7	Acceptable
	8	95.5	72.8	5	Marginally acceptable
	16	88.8	69.3	4	Unacceptable
	21	82.3	65.6	3	Unacceptable
T4	0	101.3	74.1	10	Acceptable
	5	99.5	71.9	10	Acceptable
	8	99.2	71.9	9	Acceptable
	16	99.9	70.5	7	Acceptable, few brown spots
	21	93.6	69.5	6	Acceptable, slight browning
T5	0	102.1	70.7	10	Acceptable
	5	102.4	69.7	10	Acceptable
	8	99.3	69.8	9	Acceptable
	16	100.2	70.1	8	Acceptable
	21	101.7	69.7	8	Acceptable
T6	0	100.9	73.7	10	Acceptable
	5	99.6	72.6	10	Acceptable
	8	99.5	70.9	9	Acceptable
	16	100.5	72.2	8	Acceptable
	21	101.2	71.9	7	Acceptable, slight browning
T7	0	100.5	71.6	10	Acceptable
	5	100.5	72.2	10	Acceptable
	8	100.1	72.6	9	Acceptable
	16	100.6	73.0	9	Acceptable
	21	95.2	71.4	7	Acceptable, slight browning
T8	0	98.8	68.3	10	Acceptable
	5	98.6	68.0	10	Acceptable
	8	98.6	68.7	9	Acceptable
	16	98.6	68.8	9	Acceptable
	21	97.7	69.2	8	Acceptable

*NT - not tested

Table 9.3 - Summary f shelf-life values obtained from peeled p tat es treated with agar based coatings

Treatments	Appearance of Coating	Shelf-life (days)
T1 (Control)	Not applicable	1
T2	Not applicable	5
T3	Non-uniform coat/glaze	8
T4	Thin glaze, desirable	21
T5	Thick glaze	21
T6	Weak but uniform coat	21
T7	Thick uniform coat	21
T8	Thick uniform coat	21

EXAMPLE 10

The object of this experiment was to evaluate the effects of various amount of coating in combination with different mixtures of anti-browning agents.

Sebago potatoes each weighing about 150g were peeled using an abrasive peeler (P102 Peeler by Pelatori Polivalenti of Italy) in batches of 8kg. Peeled potatoes were washed using tap water and divided into 10 lots corresponding to the treatments shown in Table 10.1 below. The vegetable gum coating and anti-browning agents were applied in two stages: (1) Solution I contained various sodium alginate solutions (Table 10.1); and (2) Solution II was a combination of anti-browning agents (ascorbic acid, citric acid and calcium chloride). Calcium chloride was added in Solution II as the firming agent of sodium alginate. All solutions were prepared at room temperature and stored at 4°C overnight. Each peeled potato receiving the alginate coating was immersed into Solution

I for about 5 minutes, and allowed to drip for about 20 seconds, followed by immersion into Solution II which resulted in a clear homogenous coat/film over the entire surface of the potatoes. It took about 10-20 minutes to complete the second immersion. After draining in a colander, 4 peeled potatoes were placed in semi-permeable polyethylene blend plastic bag (175 x 190 mm). All plastic packages were heat sealed using a manual sealer (Venus Model VH400). An additional treatment (T1) which acted as a control was prepared by dipping the peeled potatoes in water. There were 4 replications per treatment. All samples were stored at 4±0.5°C.

Treatment effectiveness was evaluated by measuring colour changes at the peeled surface of treated samples and control during storage. To measure colour objectively, the CIELAB's "*L*" (light-dark), "*a*" (red-green) and "*b*" (yellow-blue) for randomly selected surface areas were measured using a Minolta Chroma meter, Model CR300 with a 8 mm specimen port. To evaluate the change in colour, hue angle was also calculated from the tristimulus data ("a" and "b"). Hue angle values of 0°, 90°, 180° and 270 indicate red, yellow, green, and blue, respectively. Hue angle values close to 90° indicate more browning.

A subjective visual evaluation was also conducted to assess the change in colour during storage. The scoring system described in Table 1.2 of Example 1 was also used to subjectively assess the visual acceptability of fresh peeled potatoes. A colour score of "6" was considered marginally acceptable. End of shelf-life corresponds to a visual score of 5.

Table 10.1 - Treatments for whole peeled potatoes prepared using various coatings and anti-browning agents

Treatment	Solution I (coating)		Solution II*	
	Sodium Alginate	Viscosity	Ascorbic Acid (%w/v)	Citric Acid (%w/v)
T1 (Control)	-	-	-	-
T2	3% Manucol DH	Low	1	0.25
T3	3% Manucol DH	Low	2	0.50
T4	3% Manucol DH	Low	4	1.00
T5	2% Manucol DH & 1% Manucol DM	Medium	1	0.25
T6	2% Manucol DH & 1% Manucol DM	Medium	2	0.50
T7	2% Manucol DH & 1 % Manucol DM	Medium	4	1.00
T8	3% Manucol DM	High	1	0.25
T9	3% Manucol DM	High	2	0.50
T10	3% Manucol DM	High	4	1.00

*Solution II contained 1.5% calcium chloride.

Results and Discussion

The results of the test are shown in Tables 10.2 and 10.3 below.

As the information in Tables 10.2 and 10.3 shows, it is possible to extend the shelf-life of abrasive-peeled potatoes up to about 21 days at 4°C using treatments T_3, T_4, T_6, T_7, T_9, and T_{10}. This extension in shelf-life is more than 500% compared to the shelf-life of control or water-dipped samples that were packaged and stored under similar conditions. Amongst these treatments, T_3 was found to give a 21 day shelf-life requiring low levels of sodium alginate coating and anti-browning agents. The weight gained by the use of treatment T_3 was measured to be only 4.7% (weight of coating per weight of peeled potatoes) which was calculated to be equivalent to 0.14% kg sodium alginate/kg peeled potatoes (Table 10.3). This very low level of usage of sodium alginate, ascorbic acid (2%) and citric (0.5%) in T_3 would be economically acceptable to processors.

The results of this test suggest that the most significant factor affecting shelf-life was the level of anti-browning agents (Solution II). The effects of the amount or thickness of coating (expressed here as weight gained) was not very significant under the conditions used in this test. There was no additional shelf-life gained by the use of "thicker" coatings because after 21 days at 4°C, shelf-life was limited by the appearance of yeast growth not by enzymatic browning. The use of "thicker" coatings and high levels of ant-browning agents may give significant benefits if an acceptable organic preservative such as benzoic acid or potassium sorbate can inhibit yeasts growth after 21 days of storage.

Finally, the choice of coating formulation would largely depend on the target "buyers/users" of peeled potatoes. Some people may prefer less visible coating which can be prepared using treatments T_3 or T_4, while others may prefer "easy-to-peel" thicker coating prepared by treatments T_6, T_7, T_9, and T_{10}.

Table 10.2 - Results of c lour assessment of peeled potat es stored at 4°C

Treatment	Storage days	Hue Angle	"L" value	Visual score	Comments
T1: Control	0	98.5	70.1	10	Acceptable
	4		67.16	6	Acceptable
	7	82.3	6.4	4	Unacceptable
	14	78.6	68.2	3	Unacceptable
	21	-	-	-	NT*
	26	-	-	-	NT*
T2:	0	95.7	72.6	10	Acceptable
	4	97.9	73.4	9	Acceptable
	7	92.8	70.7	6	Acceptable
	14	86.6	68.7	5	Unacceptable
	21	-	-	-	Unacceptable
	26	-	-	-	
T3	0	99.8	75.4	10	Acceptable
	4	100.1	74.7	10	Acceptable
	7	100.2	74.3	9	Acceptable
	14	100.2	73.9	8	Acceptable
	21	95.9	71.9	6	Acceptable, slight browning
	26	NT	NT	4	Unacceptable
T4	0	99.1	75.9	10	Acceptable
	4	100.4	78.0	10	Acceptable
	7	102.5	73.9	9	Acceptable
	14	102.7	76.7	9	Acceptable
	21	102.9	75.6	9	Acceptable
	26	-	-	5	Mould & yeast, No browning
T5	0	100.6	72.5	10	Acceptable
	4	98.4	70.7	10	Acceptable
	7	93.2	70.9	8	Acceptable
	14	82.4	65.6	5	Unacceptable
	21	-	-	-	NT*
	26	-	-	-	NT*
T6	0	100.0	71.7	10	Acceptable
	4	100.8	73.5	10	Acceptable
	7	99.5	73.1	9	Acceptable
	14	99.1	72.6	9	Acceptable
	21	90.7	69.9	9	Acceptable
	26	-	-	5	Unacceptable, yeast growth
T7	0	101.3	72.6	10	Acceptable
	4	101.4	74.2	10	Acceptable
	7	101.5	73.1	9	Acceptable
	14	101.9	73.8	9	Acceptable
	21	101.5	74.1	8	Acceptable
	26	-	-	5	Unacceptable, yeast growth
T8	0	100.2	70.3	10	Acceptable
	4	100.2	70.5	10	Acceptable
	7	90.9	69.7	9	Acceptable
	14	81.9	66.5	8	Acceptable
	21	-	-	5	Unacceptable
	26	-	-	-	NT*
T9	0	102.5	62.8	10	Acceptable
	4	98.6	71.3	10	Acceptable
	7	99.3	71.8	9	Acceptable
	14	97.4	71.7	8	Acceptable
	21	90.5	69.6	7	Acceptable
	26	-	67.3	5	Unacceptable, browning
T10	0	99.4	71.8	10	Acceptable
	4	99.9	72.8	10	Acceptable
	7	100.1	73.4	9	Acceptable
	14	99.9	73.1	9	Acceptable
	21	100.9	72.9	8	Acceptable
	26	-	-	5	Mould & yeast growth, no browning

*NT - not tested

Table 10.3 - Summary of shelf-life values obtained from abrasively-peeled potatoes prepared using various coatings and anti-browning agents

Treatments	% Weight Gained by Coating	Shelf-life (days)
T1 (Control)	-	4
T2	4.7	7
T3	4.7	21
T4	4.7	>21 to < 26
T5	7.1	7
T6	7.1	>21 to <26
T7	7.1	>21 to <26
T8	8.3	7
T9	8.3	>21 to <26
T10	8.3	>21 to <26

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

CLAIMS

1. A method for preserving exposed underground plant structures which comprises applying an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent to the exposed plant structure.

2. A method for preserving exposed underground plant structures which comprises the steps of:

(a) applying an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent to the exposed plant structure; and

(b) storing the coated exposed plant structure in a semi-permeable package.

3. A method as claimed in Claim 1 or Claim 2, wherein underground plant is a stem tuber, swollen taproot, swollen hypocotyl, bulb or underground bud.

4. A method as claimed in Claim 3, wherein the stem tuber is a potato or sweet potato.

5. A method as claimed in Claim 3, wherein the swollen taproot is a carrot.

6. A method as claimed in Claim 3, wherein the swollen hypocotyl is a beetroot.

7. A method as claimed in Claim 3, wherein the bulb or underground bud is an onion.

8. A method as claimed in any one of the preceding claims, wherein the edible coating is a polysaccharide gum or mixture of polysaccharide gums.

9. A method as claimed in Claim 8, wherein the polysaccharide gum is alginate or derivatives thereof; vegetable gum; agar; modified starch; microbial polysaccharides; or mixtures thereof.

10. A method as claimed in Claim 9, wherein the alginate is sodium, potassium, ammonium, ammonium-calcium or an sodium-calcium salt of alginic acid or propylene glycol alginate.

11. A method as claimed in Claim 9 or Claim 10, wherein the alginate is sodium alginate.

12. A method as claimed in Claim 9, wherein the microbial polysaccharide is gellan gum.

13. A method as claimed in any one of the preceding claims, wherein the formation of the edible coating is assisted by the use of at least one food additive.

14. A method as claimed in Claim 13, wherein the food additive is an emulsifying, gelling, stabilizing, thickening and/or firming agent.

15. A method as claimed in Claim 13 or Claim 14, wherein the food additive is a source of calcium ions.

16. A method as claimed in Claim 15, wherein the source of calcium ions is calcium carbonate, sulphate, chloride, phosphate, lactate or tartrate.

17. A method as claimed in Claim 15 or Claim 16, wherein the source of calcium ions is calcium chloride.

18. A method as claimed in any one of the preceding claims, wherein the anti-browning agent is an anti-oxidant or reducing agent, an acidulant, a chelating agent, a phenolase inhibitor, an inorganic salt, an enzyme or mixtures thereof.

19. A method as claimed in Claim 18, wherein the anti-oxidant or reducing agent is sulfhydryl compound, ascorbic acid or derivatives or isomers thereof.

20. A method as claimed in Claim 18, wherein the acidulant is citric acid or derivatives or isomers thereof.

21. A method as claimed in Claim 18, wherein the chelating agent is ethylenediaminetetraacetic acid (EDTA) or sodium acid pyrophosphate.

22. A method as claimed in Claim 18, wherein the inorganic salt is a calcium salt.

23. A method as claimed in Claim 22, wherein the calcium salt is calcium carbonate, sulphate, chloride, phosphate or tartrate.

24. A method as claimed in any one of Claims 1 to 20, 22 and 23, wherein the anti-browning agent is a combination of ascorbic acid or derivatives or isomers thereof, citric acid or derivatives or isomers thereof and calcium chloride.

25. A method as claimed in any one of Claims 2 to 24, wherein the package is a parcel, film, container, box or bag.

26. A method as claimed in any one of Claims 2 to 25, wherein the package is semi-permeable to oxygen and carbon dioxide.

27. A method as claimed in any one of Claims 2 to 26, wherein the semi-permeable package is wholly or partly composed of a single or multilayer polymeric film having an oxygen transmission rate (OTR) of about 4,000 to about 8,000 cc/m^2-day (23°C, 70% relative humidity).

28. A method as claimed in any one of Claims 2 to 27, wherein the semi-permeable package is a single layer polymeric film of 50-55 micron low density polyethylene.

29. A method as claimed in any one of the preceding claims, wherein the preserved underground plant structure is stored at a temperature below about 10°C.

30. A method as claimed in Claim 29, wherein the temperature is in the range of about -1°C to about 5°C.

31. A composition for preserving exposed underground plant structures which comprises an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent.

32. A kit for preserving exposed underground plant structures which comprises:

(a) an edible coating which acts as a carrier for an anti-browning agent; and

(b) at least one anti-browning agent,

said components (a) and (b) being held in the kit separately for simultaneous, sequential or separate use.

33. An underground plant having an exposed structure which is coated with an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent so as to preserve the exposed tissue.

34. A package for preserving exposed underground plant structures which comprises a semi-permeable material containing an underground plant having an exposed structure which is coated with an edible coating which acts as a carrier for an anti-browning agent and at least one anti-browning agent.

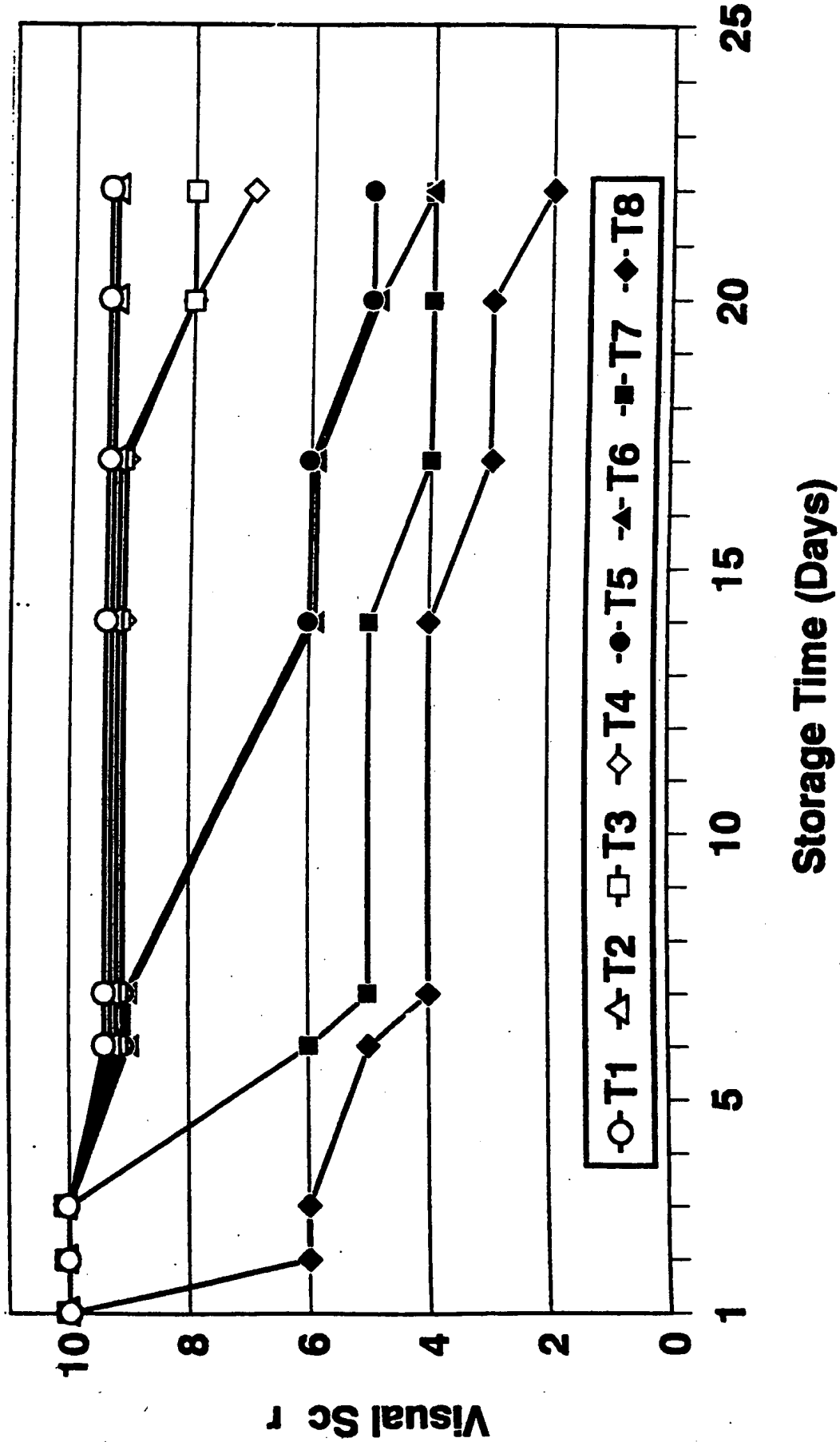

FIGURE 1

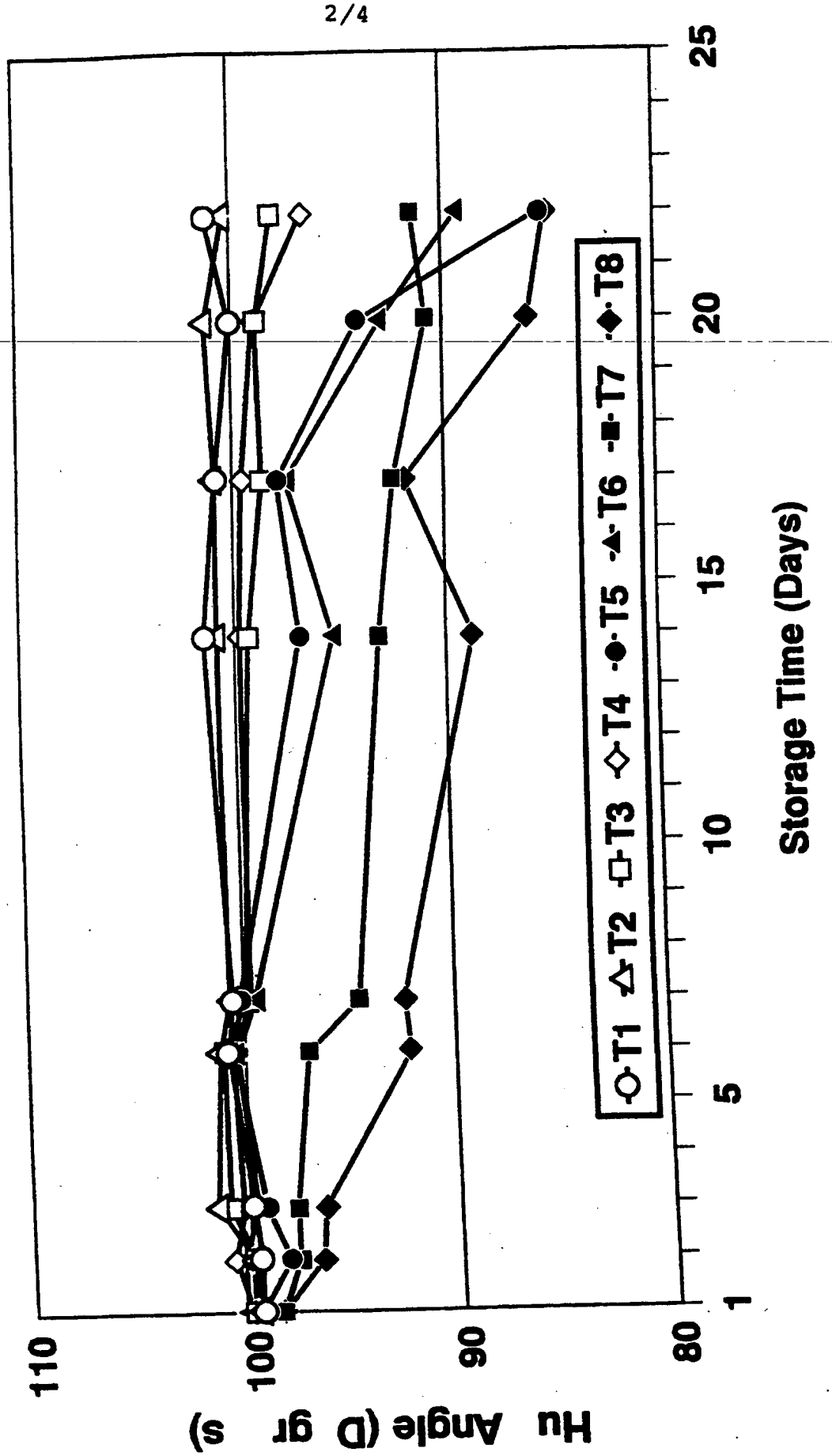
Hu Angle (D gr s)
110
100
90
80
1
5
10
15
20
25
Storage Time (Days)
T1
T2
T3
T4
T5
T6
T7
T8

FIGURE 2

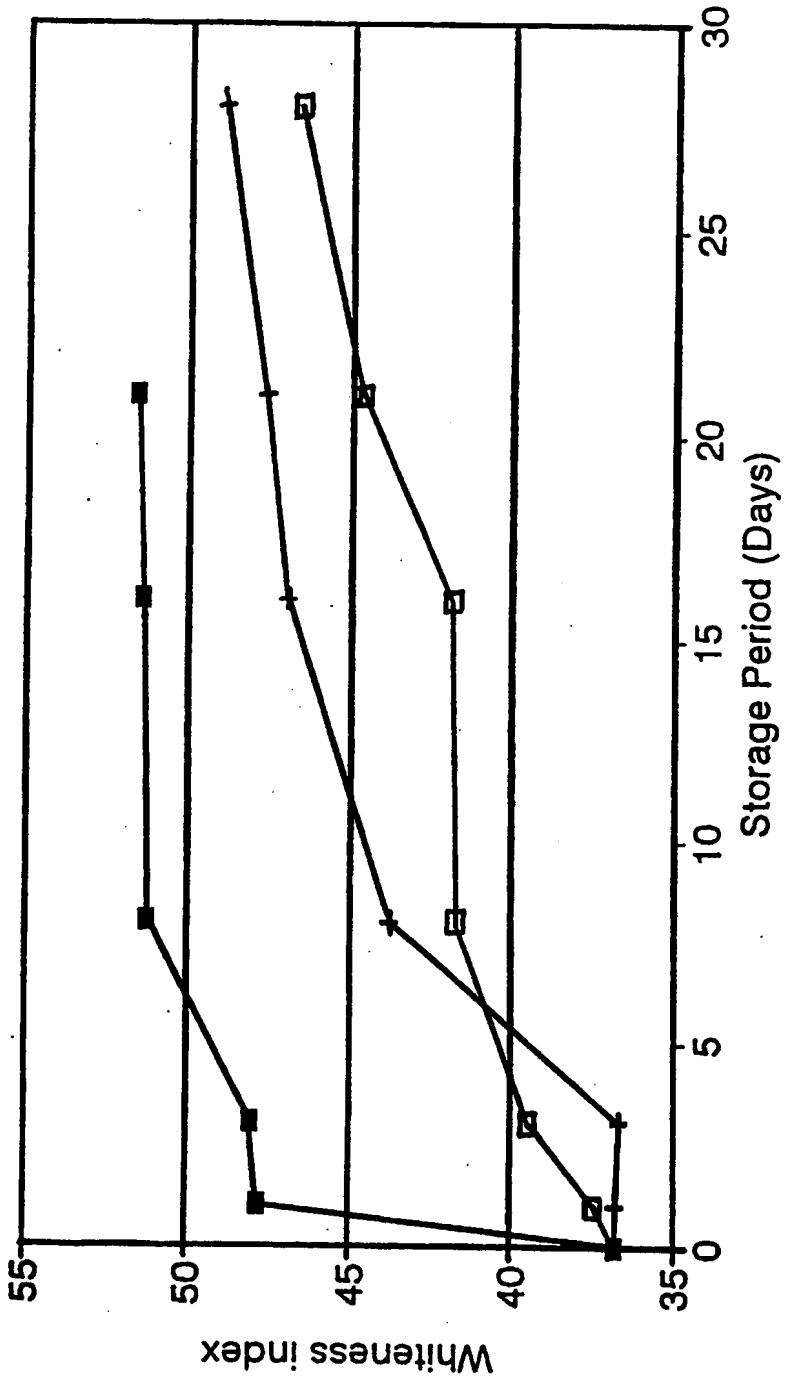

FIGURE 3

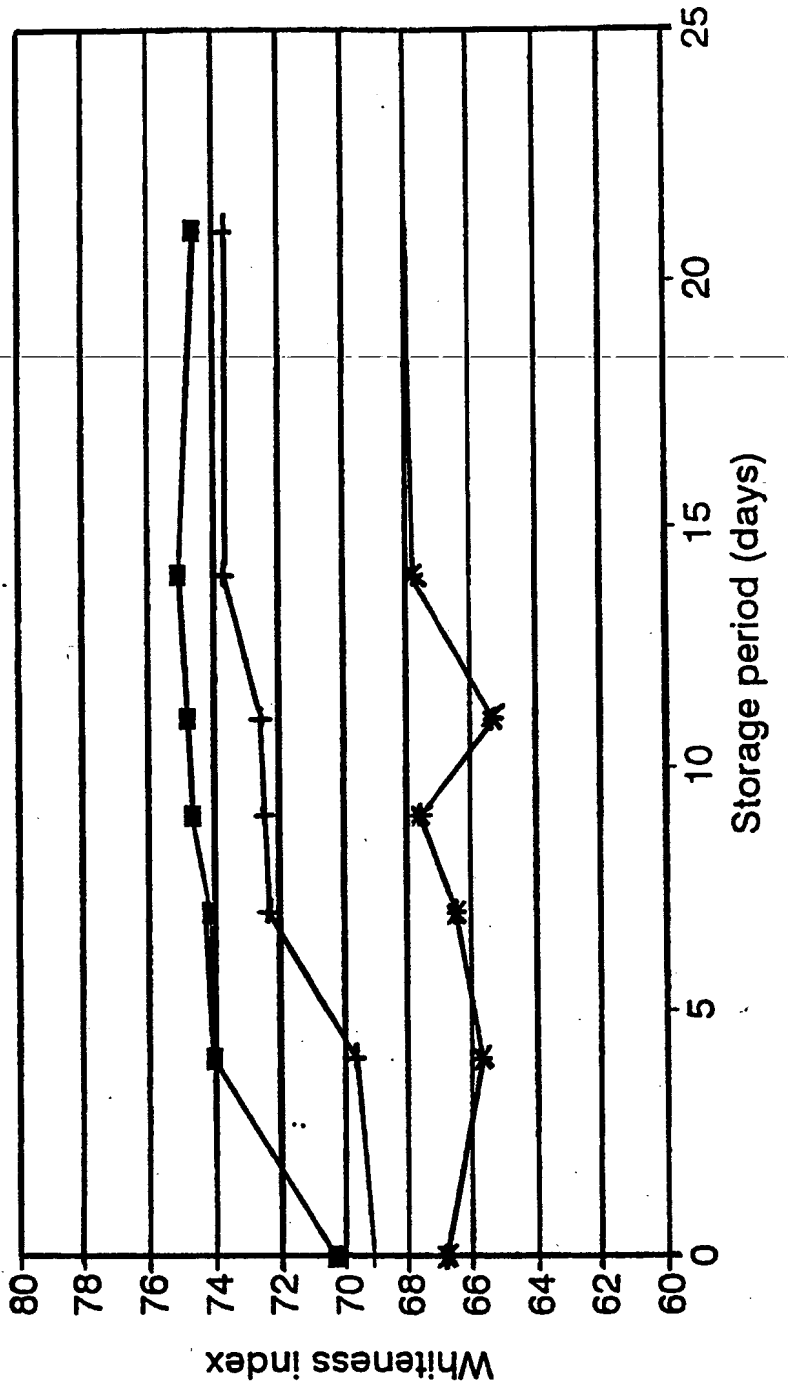

FIGURE 4